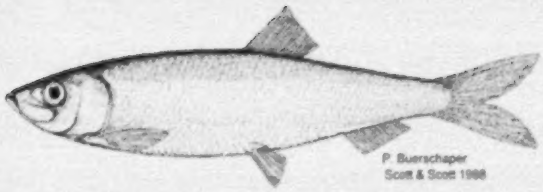
Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat
Science Advisory Report 2015/040

Maritimes Region

2015 ASSESSMENT OF 4VWX HERRING



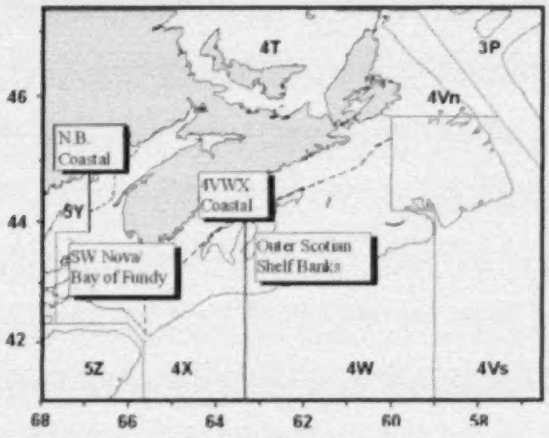


Figure 1. 4VWX herring management area and stock component locations.

Context:

In support of scientific advice for the 2014/15 and 2015/16 fisheries, the 2015 assessment of the 4VWX herring stock complex was reviewed through a Science Advisory Process. The meeting was held March 25-26, 2015, in Dartmouth, N.S., to review and evaluate biological and fishery information on 4VWX herring status as a basis for establishing quota for the 2014/15 fisheries, as required in the Integrated Fisheries Management Plan. The terms of reference included an evaluation of the Southwest Nova Scotia (SWNS)/Bay of Fundy spawning component, compilation and review of information regarding the offshore Scotian Shelf and the coastal Nova Scotia spawning components, an update on southwest New Brunswick migrant juvenile fishery component, and recommendations to management on stock status. Participants included scientists, fishery managers, and representatives of the industry, provincial governments, and other stakeholders. The last assessment of this resource was in 2013.

The 2003 (Evergreen) Scotia-Fundy Herring Integrated Fisheries Management Plan (IFMP) set out principles, conditions, and management measures for the 4VWX herring fisheries (DFO 2003). The main principle stated in the plan is "the conservation of the herring resource and the preservation of all of its spawning components". The background for the conservation objectives was first developed and reviewed by Sinclair (1997). Three conservation objectives appear in the plan:

1. *To maintain the reproductive capacity of herring in each management unit through:*
   - *persistence of all spawning components in the management unit;*
   - *maintaining biomass of each spawning component above a minimum threshold;*
   - *maintaining a broad age composition for each spawning component; and*
   - *maintaining a long spawning period for each spawning component.*
2. *To prevent growth overfishing:*
   - *continue to strive for fishing mortality at or below $F_{0.1}$.*
3. *To maintain ecosystem integrity/ecological relationships ("ecosystem balance"): Herring is prominent in the diet of many fish, birds and marine mammals and should be managed with these interactions in mind.*

Specific targets include:

- *maintaining spatial and temporal diversity of spawning; and*
- *maintaining herring biomass at moderate to high levels.*

Progress against these objectives was evaluated at this meeting. Since 1995, the herring stock assessment and related research has been increasingly dependent on a number of projects undertaken with the assistance of the fishing industry. These include industry sampling for biological characteristics of the landings, as well as acoustic surveys using industry vessels and tagging. A major review of the assessment framework was conducted in 2006/07 (DFO 2007) followed by a framework meeting in 2011. No model was chosen but recommendations for the assessment were provided in the report (DFO 2011). In 2012, a conservation limit reference point (LRP) was set for spawning biomass in Scots Bay and German Bank to be evaluated based on the three-year moving average (Clark et al. 2012). The next framework meeting is scheduled for 2017.

This Science Advisory Report is from the March 25-26, 2015, Assessment of 4VWX Herring. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

SW Nova Scotia/Bay of Fundy

- Landings for the 2012/2013 and 2013/2014 quota years were 46,554t and 50,250t against a Total Allowable Catch (TAC) of 50,000t each year for the SW Nova Scotia/Bay of Fundy (SWNS/BoF) component.
- Landings have tracked the TAC since 2002, with most of the quota (and on occasion slightly above) being taken each year since 2002.
- Although there is uncertainty associated with the biomass estimates, longer term trends in biomass appear to be evident for the SWNS/BoF spawning component: a decreasing trend in the German Bank area from 1999 to present, and an increasing trend in the Scots Bay area since 2005.
- In 2012, a conservation limit reference point (LRP) for the SWNS/BoF herring spawning component (German Bank and Scots Bay) was identified as the 2005-2010 average acoustic survey biomass (371,067t), below which, the risk of serious harm is unacceptable (Clark et al. 2012).
- The three-year moving average increased above the LRP in 2011 and changed very little in 2012. Since 2012, the three-year moving biomass average has been increasing slightly each year. Biomass estimates have fluctuated about the LRP since 2010. Confidence intervals include the LRP in three of the last four years, the exception being 2012 when the confidence interval was above the LRP.
- The biomass of spawning fish estimated to be on Trinity Ledge from 2012 to 2014 is low relative to values observed in the early 2000s. Fishing during the spawning season on Trinity Ledge has the potential to jeopardize the persistence of this spawning unit.
- The broad range of ages observed in the commercial landings indicates that the conservation objective to maintain a broad range of ages is generally being met.
- There has been a trend of declining mean weight at age. Declining trends in commercial mean weight at age since the 1970s have reduced productivity of the stock.
- A harvest strategy, which continues to exercise caution, is appropriate.

Offshore Scotian Shelf Banks

- Since 1996, a fishery has occurred on feeding aggregations on the offshore banks, primarily in May and June, with landings ranging from 20,261t in 1997 to 58t in 2014. Landings from 2012 to 2014 were amongst the lowest in the time series.
- No industry surveys were conducted on the offshore Scotian Shelf in 2013 or 2014. In the fall of 2014, industry conducted searches in the offshore but failed to find any spawning aggregations.
- In the absence of recent information about stock status there is no basis for evaluating the current 12,000t catch allocation. The industry is again encouraged to explore and undertake structured surveys of the offshore area.

Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia

- From 2009 to 2014, landings in the Little Hope/Port Mouton area have ranged between 2,150t and 3,731t, and have been near or above the allocation.
- From 2009 to 2014, landings in the Eastern Shore area have ranged between 771t and 6,045t, and are generally below the allocation.
- Landings were minimal for Glace Bay with 2t in 2013 and 1t in 2014.
- The Bras d'Or Lakes area remained closed to herring fishing. It has been noted since 1997 that the status of herring in the Bras d'Or Lakes is cause for concern. In the absence of current abundance information the Bras d'Or Lakes should remain closed.
- Individual spawning groups within the coastal component are considered vulnerable to fishing because of their relatively small size (biomass) and proximity to shore. For this reason, a large effort increase in new areas has a potential to markedly reduce abundance in the absence of information about the status of the specific spawning group.
- With the exception of the four main areas, the size of various additional spawning groups and landings from these groups are poorly documented. In addition to the traditional bait and personal-use fisheries, directed roe fisheries have occurred on several spawning grounds since 1996.

Southwest New Brunswick Migrant Juvenile

- The southwest New Brunswick weir and shutoff fisheries have relied, for over a century, on the aggregation of juvenile herring (ages 1-3) near shore at the mouth of the Bay of Fundy.
- Fish caught in the New Brunswick weir and shutoff fishery were mostly juveniles (93% and 96% at either age 1 or age 2 in 2013 and 2014, respectively).
- For the time series presented, current landings are at or near the lowest observed. In 2012, the number of weirs with landings was at a historical low, but subsequently increased to 49 in 2013. In 2014, the number of weirs with landings again decreased to 26.
- Abundance of herring available to the weirs is unknown.
- The primary sources of information for assessing this component are the landings, which have declined markedly from the 1980s to present. The landings time series for this fishery may not be indicative of abundance because catches are extremely susceptible to many factors in addition to abundance, including effort.

BACKGROUND

Species Biology

Atlantic herring (*Clupea harengus*) is a pelagic species found on both sides of the North Atlantic. Herring spawn in discrete locations to which they have a strong affinity. The majority of herring in the 4VWX area are fall spawners. These herring mature in 4VWX and first spawn at three or four years of age, then begin an annual pattern of spawning, over-wintering, and summer feeding. This often involves considerable migration and mixing with members of other spawning components and stocks. Fishing takes place on dense summer feeding, over-wintering, and spawning aggregations.

The 4VWX management unit contains a number of spawning areas, separated to various degrees in space and time. Spawning areas in close proximity with similar spawning times, and which share a larval distribution area, are considered part of the same component. These undoubtedly have much closer affinity than spawning areas that are widely separated in space or time and do not share a common larval distribution. Some spawning areas are large and offshore, whereas others are small and more localized, sometimes very near shore or in small embayments. The stock structure is complicated further as herring migrate long distances and mix outside of the spawning period both with members considered part of the same component and with members of other components. For the purposes of evaluation and management, the 4VWX herring fisheries are divided into four components:

1. SW Nova Scotia/Bay of Fundy spawning component
2. Offshore Scotian Shelf banks spawning component
3. Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia spawning component
4. SW New Brunswick migrant juveniles

Each component except southwest (SW) New Brunswick migrant juveniles has several spawning areas, and there is mixing of fish among spawning components outside of the spawning period.

Fishery

Fisheries in 4VWX have been dominated by purse seine (80-90%), followed by gillnet, weir, shutoff and trap.

Landings for the 2012/2013 and 2013/2014 quota years were 46,554t and 50,250t against a Total Allowable Catch (TAC) of 50,000t each year for the SW Nova Scotia/Bay of Fundy component (Table 1). Landings have tracked the TAC since 2002, with most of the quota (and on occasion slightly above) being taken each year since 2002. In 2010, as a result of an industry decision late in the season, 9,466t of quota was left in the water (Figure 2).

Table 1. Reported landings (thousands of tonnes) and TAC for the 4WX herring management unit by component from 2005 to 2014 with averages for recent and prior decades.

Year	Avg. 1970-79	Avg. 1980-89	Avg. 1990-99	Avg. 2000-09	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
4WX SW Nova Scotia TAC[1]	106	106	112	69	50	50	50	55	55	55	50	50	50	50
4WX SW Nova Scotia[1]	131	131	96	66	49	50	50	55	54	46	50	48	47	50
4VWX Coastal NS[2]	<1	<1	4	7	7	7	5	4	10	6	4	3	4	5
Scotian Shelf Banks[2]	38	<0.1	13	6	5	10	5	1	9	12	10	1	2	0
SW New Brunswick[2]	26	24	24	15	13	13	31	6	4	11	4	1	6	2
Total Landings	172	155	137	93	74	79	92	66	77	74	68	52	58	57

[1] Quota year from October 15th of the preceding year to October 14th of the current year.
[2] Calendar year from January 1st to December 31st.

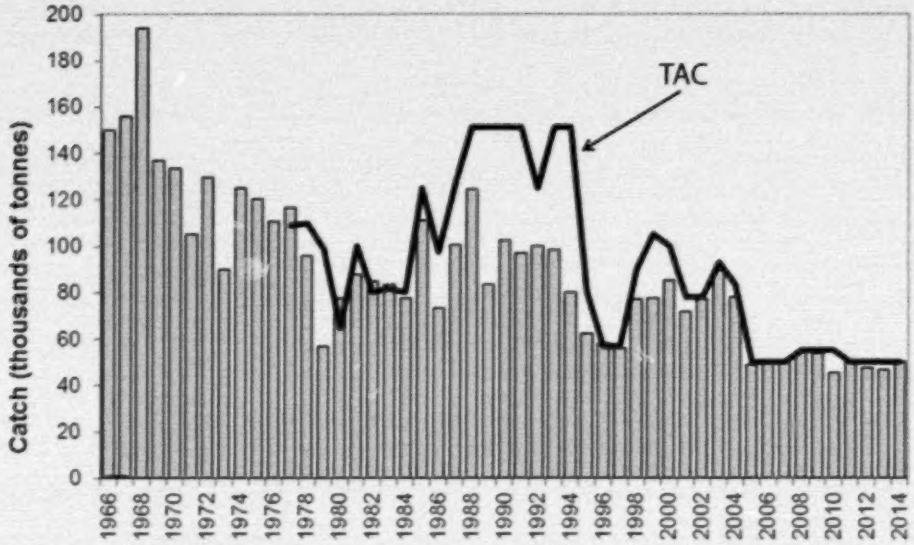


Figure 2. Landings (thousands of tonnes) and TAC for the SW Nova Scotia/Bay of Fundy spawning component.

Additional landings of 11,778t were taken in the non-stock components (outside the quota area) in 2013 for a total of 58,332t, with increased landings from the New Brunswick weirs and shutoffs, the Scotian Shelf Banks and the Coastal Nova Scotia component. In 2014, non-stock landings were 6,966t - resulting in a total of 57,216t, with decreased landings from the New Brunswick weirs and shutoffs and the Scotian Shelf Banks, but increasing in the Coastal Nova Scotia component.

The largest proportions of purse seine landings came from fishing grounds on German Bank (29% in 2013 and 30% in 2014), Grand Manan (27% in 2013 and 20% in 2014) and Gannet Dry Ledge (13% in 2013 and 26% in 2014) areas. The proportion occurring in Scots Bay decreased from 11% in 2012 to 10% in 2013 and 9% in 2014.

Industry and management have explored means of managing the complexity within each component (such as distributing fishing effort among spawning areas according to their relative size) and taking account of the interaction among components (such as fishing restrictions on some areas of mixing). Prior to 2005, there was targeting of young fish and a high proportion of juveniles in the landings resulted in lost potential yield. From 2005 to 2008, the total removals by number (all age classes combined) were reduced by close to 50% relative to 2004; however, they increased in 2009 with the catch of a large proportion of two-year olds (45%) by number.

The total removals of two-year olds made up 60% of the overall TAC by number in 2010 as a result of a strong age 2 cohort entering the fishery (also observed as a strong age 3 cohort in 2011) and the targeting of very small fish. Since the fall of 2010, there have been self-imposed measures by industry to monitor and restrict catches of fish less than 18cm in length.

ASSESSMENT

SW Nova Scotia/Bay of Fundy (SWNS/BoF)

In the last three quota years, there has been no indication of a strong year-class, but instead three relatively consistent cohorts. The 2011-2012 landings had a catch composition of 25% age 2 and 13% age 3 fish. The 2012-2013 landings were primarily age 2 and age 3 fish, 55% of the catch by number

(Figure 3). Similarly, the majority of the 2013-2014 landings were age 2 and age 3 fish, 59% of the catch by number (Figure 3). However, the fishery catch at age is also showing a greater proportion of age 5+ fish as three relatively strong year classes are aging (2005, 2007 and 2008 year classes) (Figure 4). As a result, age 5+ fish are also contributing a substantial portion of the landings (34% and 29% of the catch in 2013 and 2014 by number, respectively).

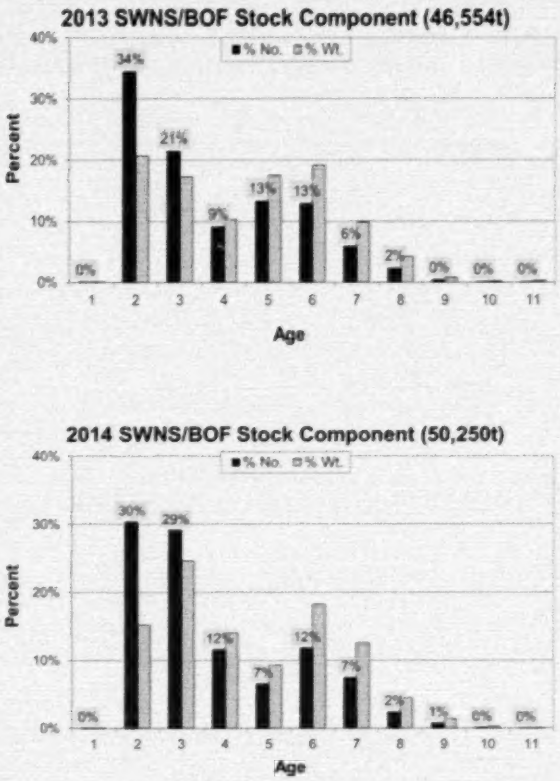


Figure 3. Fishery catch at age (% numbers and % weight) for SWNS/BoF spawning component (2012-13, 2013-14 quota years).

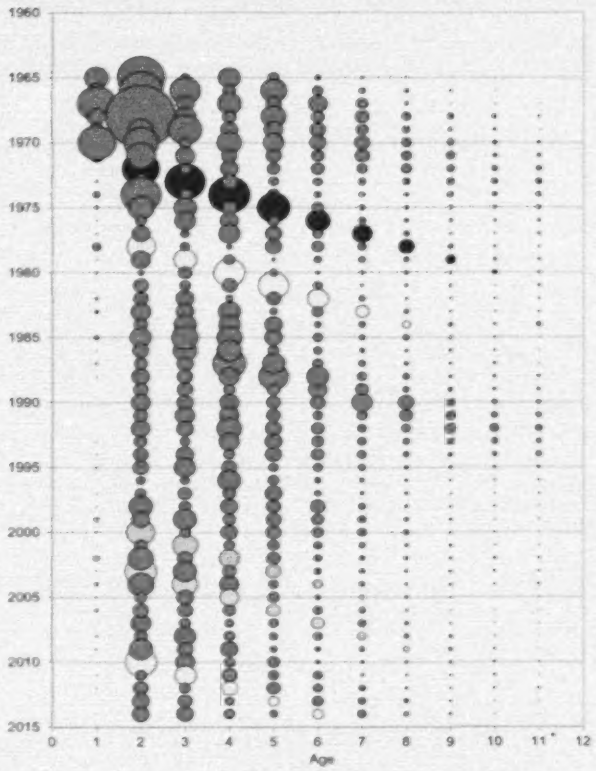


Figure 4. Historical relative numbers at age (denoted by circle size) for SWNS/BoF spawning component from 1965-2014. Selected year-classes are indicated by colours.

The total number of fish calculated to be removed by the fishery was 432 million in 2012, 429 million in 2013, and 448 million in 2014, suggesting relatively similar landings in the last three years.

Acoustic Surveys

The acoustic age composition is assumed to be representative of the overall spawning biomass at these ages. Acoustic survey catch at age had a broad age distribution of fish from ages 3-11. Similarly, the commercial catch at age had a broad age distribution of fish from ages 2-11. The proportion of fish at age 6 and older was 34% (2013) and 40% (2014) in the acoustic survey catch at age compared with 21% (2013) and 22% (2014) in the fishery (Figure 5). The mean age of the acoustic survey catch at age was 5.0 years in 2014.

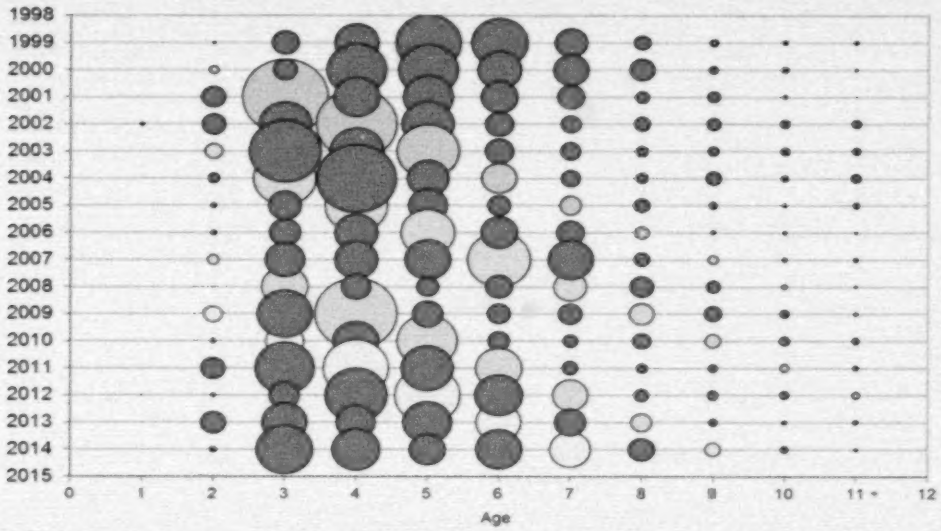


Figure 5. Acoustic survey relative numbers at age (denoted by circle size) for the overall SW Nova/Bay of Fundy spawning component. Selected year-classes are indicated by colours

Industry-led surveys with automated acoustic recording systems deployed on commercial fishing vessels were used to document the distribution and abundance of spawning herring. Scheduled surveys were conducted approximately every two weeks (between late June and early October) on the main spawning grounds and an index of spawning stock biomass (SSB[1]) for each component was estimated by summing these results (Table 2; Figure 6).

Table 2. Acoustic survey biomass index for SWNS/BoF spawning component for 1999 to 2014 (thousands of tonnes).

Location/Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average 2005-2010	Average 1999-2014
Scots Bay (inbox)	46	185	216	129	123	115	21	32	51	23	82	42	106	144	67	226	42	100
Scots Bay (outbox)	-	-	-	-	-	-	-	-	2	0	6	12	35	41	9	5	11	14
Scots Bay total	46	185	216	129	123	115	21	32	53	23	88	54	141	185	76	231	45	107
German Bank (inbox)	495	334	257	416	349	392	269	291	495	239	396	235	289	278	254	230	321	326
German Bank (outbox)								5	4	2	2	19	11	10	11	3	6	7
German Bank total	495	334	257	416	349	392	269	295	499	241	398	254	300	288	265	233	326	330
Trinity Ledge	4	1	15	9	12	12	11	16	3	1	2	2	7	3	1	5	6	6
Spec Buoy (spring)	-	-	1	-	1	-	1	-	0	0	-	2	0	-	-	-	1	1
Spec Buoy (fall)	-	-	88	-	-	-	-	0	-	-	-	-	-	-	-	-	0	44
Overall Stock Area	545	521	577	554	485	519	301	343	556	265	487	312	449	476	342	469	377	450
Seal Island	-	-	4	1	12	-	-	10	-	-	-	-	1	-	-	-	10	6
Browns Bank	-	-	45	-	-	-	-	8	-	-	-	-	-	-	-	-	8	26
Total All Areas	545	521	626	556	497	519	301	361	556	265	487	312	450	476	342	469	380	455

Seven surveys were conducted in Scots Bay in 2013 and six in 2014. Five usable structured surveys were conducted on the German Bank in both 2013 and 2014, which were used to estimate the SSB. Individual survey area coverage was good and consistent with established protocols.

[1] Throughout this document, spawning stock biomass (SSB) refers to the spawning stock biomass observed at the time of the acoustic surveys.

The biomass of spawning fish estimated on Trinity Ledge from 2012 to 2014 is low relative to values observed in the early 2000s. In both 2013 and 2014, only two acoustic surveys were conducted by one vessel the *Katrina and Kayla*; however, several additional trips to search for fish were conducted, although no schools of significant amounts were found. There were no surveys in 2013 or 2014 around Seal Island, Spectacle Buoy or Browns Bank.

The overall SWNS/BoF (Scots Bay, German Bank and Trinity Ledge) spawning biomass estimates for 2012, 2013 and 2014 were 476,000t (95% confidence interval (C.I.): +/- 89,400t), 341,694t (95% C.I.: +/- 160,115t), and 468,736t (95% C.I.: +/- 185,679t), respectively. This 2014 biomass estimate is slightly above the long term average of 450,010t (Figures 6 and 7), although there is uncertainty associated with these estimates.

It is evident that much of the recent fluctuation in the biomass estimates for the SWNS/BoF spawning complex is occurring in the Scots Bay area. In Scots Bay, biomass estimates from 2012 to 2014 were 184,800t (95% C.I.: +/- 52,600t), 76,218t (95% C.I.: +/- 20,984t), 230,930t (95% C.I.: +/- 106,514t), respectively. Industry has imposed a catch restriction of 5,000t in Scots Bay since 2006.

The total German Bank biomass was estimated to be 288,400t (95% C.I.: +/- 72,300t) in 2012, 264,527t (95% C.I.: +/- 158,733t) in 2013, and 233,034t (95% C.I.: +/- 152,051t) in 2014.

Although there is uncertainty associated with the biomass estimates, longer-term trends in biomass appear to be evident for the SWNS/BoF spawning component: a decreasing trend in the German Bank area from 1999 to present, and an increasing trend in the Scots Bay area since 2005. Caution may be warranted in the German Bank area as a result of this trend.

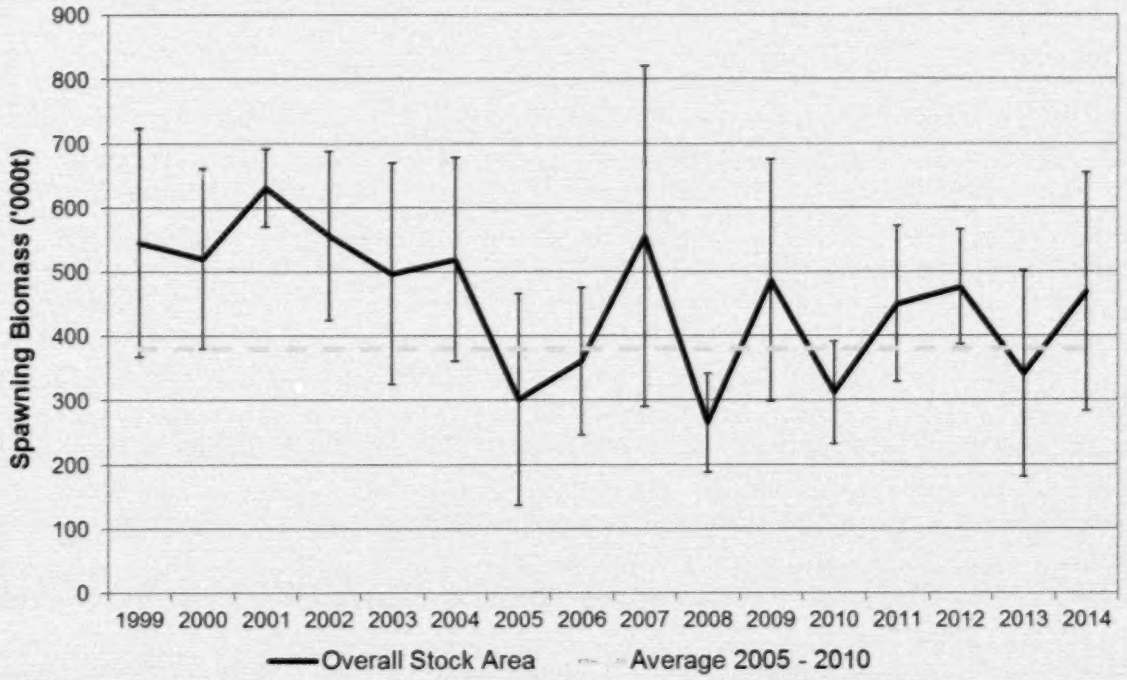


Figure 6. SSB index with 95% C.I. from acoustic surveys for the overall SWNS/BoF spawning component along with the 2005-2010 average.

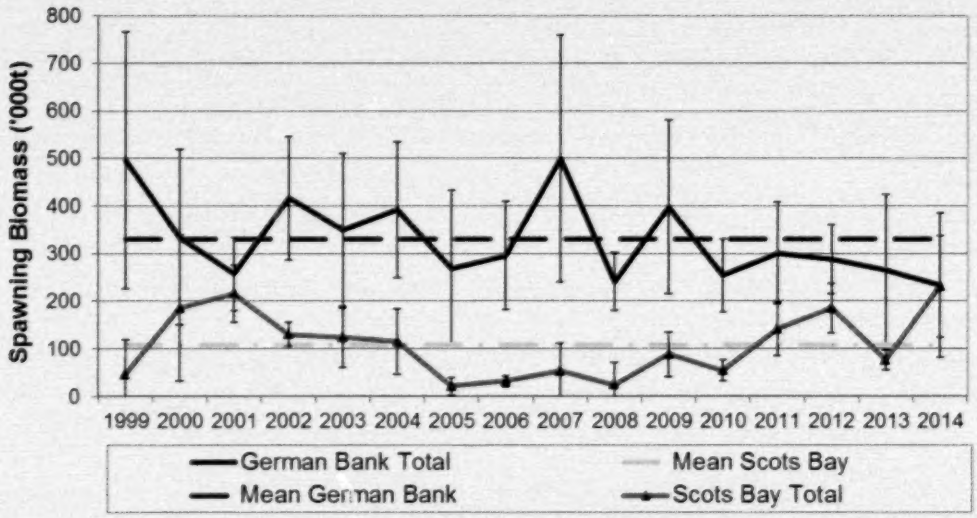


Figure 7. SSB index with 95% C.I. from acoustic surveys for German Bank and Scots Bay.

In 2012, a conservation limit reference point for the SWNS/BoF herring spawning component (German Bank and Scots Bay) was identified as the 2005-2010 average acoustic survey biomass (371,067t), below which, the risk of serious harm is considered unacceptable (Clark et al. 2012). Biomass estimates have fluctuated about this limit since 2010. Confidence intervals include the limit reference point in three of the last four years, the exception being 2012 when the confidence interval was above the LRP (Figure 8).

The three-year moving average increased above the limit reference point in 2011 and changed very little in 2012. Since 2012, the three-year moving biomass average has been increasing slightly each year (Figure 8).

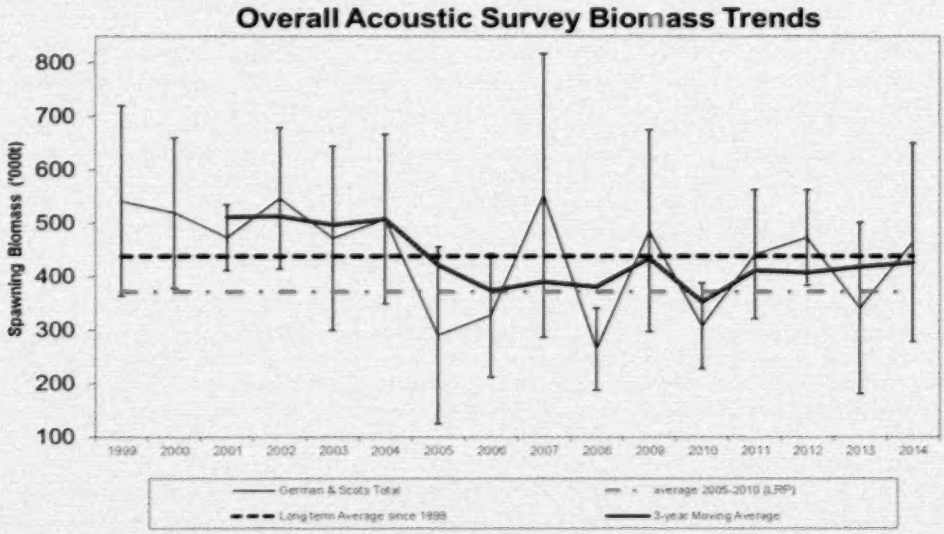


Figure 8. Relative spawning stock biomass index (with 95% confidence interval), the calculated three-year moving average, the long term average and the limit reference point for the SW Nova Scotia/Bay of Fundy spawning component (German Bank and Scots Bay).

Stock Trends and Current Status

Stock status and scientific advice for 4VWX herring is based on recommendations from the January 2011 framework (DFO 2011) and the 2012 Limit Reference Point meeting (Clark et al. 2012) as follows:

1. Report on criteria for survey and sampling and identify anomalies.
2. Signs of change using the following indicators:
    a. survey biomass trends,
    b. fishermen input,
    c. numbers or proportion at age in catch and survey,
    d. trends in relative exploitation rates using catch and acoustic survey spawning biomass estimates,
    e. trends in total mortality rate (Z) are based on age composition, and
    f. the three-year moving average survey biomass (Scots Bay and German Bank) relative to the limit reference point.

The 4VWX herring advice is based on the observations and conclusions of the conservation objectives identified in the management plan (Table 3; DFO 2003).

Table 3. Observations and conclusions on conservation objective elements from the management plan for SWNS/BoF spawning component in 2013 and 2014.

Objective	2013 and 2014: Observations
Persistence of all spawning components	Spawning was observed in the Scots Bay and German Bank areas. Spawning activity could not be determined on Seal Island or Browns Bank due to a lack of fishing or survey effort. Trinity Ledge had minimal spawning.
Maintain biomass of each component	Although there is uncertainty associated with the biomass estimates, longer-term trends in biomass appear to be evident for the SW Nova Scotia/Bay of Fundy spawning component: a decreasing trend in the German Bank area from 1999 to present and an increasing trend in the Scots Bay area since 2005. The biomass of spawning fish estimated to be on Trinity Ledge from 2012 to 2014 is low relative to values observed in the early 2000s.
Maintain broad age composition	There is currently a broad range of ages in the commercial landings (2-11), as well as in the acoustic survey catch at age (3-11). In 2013 and 2014, the proportion of the catch older than age 5 was 21% and 22% (by numbers) respectively, which is the second and third highest proportion of age 5+ caught since 1994.
Maintain long spawning period	Start of spawning in 2013 and 2014 for Scots Bay was earlier than previously recorded based on acoustic survey results since 1999. Spawning in the German Bank area appeared to start about the same time in both years and in agreement with the previous five years, but displays a trend of an earlier end date Therefore, there appear to be slight changes in the spawning periods on the two major spawning grounds. Minimal spawning occurred on Trinity Ledge.
Fishing mortality at or below $F_{0.1}$	Fishing mortality could not be determined. Relative exploitation rates based on acoustic SSB and landings increased slightly in 2013 and then decreased near to the 2012 level in 2014.
Maintain spatial and temporal diversity of spawning	Spawning in the German Bank area displays a trend of an earlier end date. Spatially, the German Bank area had a similar distribution to previous years, extending slightly further south in 2013 than previous years. Duration of

Objective	2013 and 2014: Observations
	spawning in Scots Bay was extended slightly in comparison to previous years as earlier start dates occurred. Spatially, the Scots Bay area had a wider distribution than in previous years, extending throughout the strata box. Therefore, spawning periods are being maintained both temporally and spatially on the two major spawning grounds. Trinity Ledge spawning is very restricted in space and time. There is a lack of documented spawning in other areas.
Maintain biomass at moderate to high levels	Biomass estimates have fluctuated about the LRP since 2010. Confidence intervals include the LRP in three of the last four years the exception being 2012 when the confidence interval was above the LRP.
Maintain three-year moving average above the lower reference point	The three-year moving average increased above the limit reference point in 2011 and changed very little in 2012. Since 2012, the three-year moving biomass average has been increasing slightly each year.

Observations on Mean Weight

There has been a trend of declining mean weight at age for the SWNS/BoF component of the 4WX herring fishery (Figure 9). Declining trends in commercial mean weight at age since the 1970s have reduced productivity of the stock.

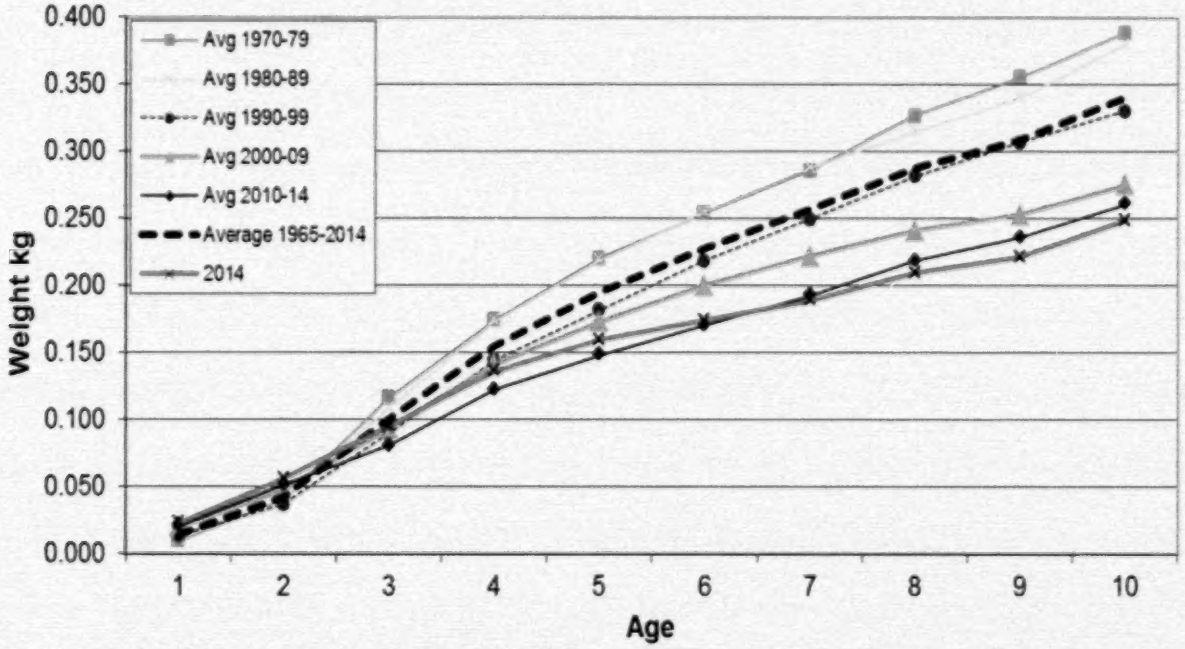


Figure 9. Fishery mean weights at age for the SWNS/BoF component for 2014 season compared with the decadal averages, overall time series for 1965-2014, and the previous five-year average (2010 to 2014).

Offshore Scotian Shelf Banks

Since 1996, a fishery has occurred on feeding aggregations on the offshore banks, primarily in May and June, with landings ranging from 20,261t in 1997 to 58t in 2014 (Figure 10). Landings from 2012 to 2014 were amongst the lowest in the time series. The variability in catch levels can be due to factors

such as fish being too deep, weather, and market conditions, in addition to a lack of herring abundance in these areas.

In 2013 and 2014, the age composition of the catch was primarily adult herring (age 3+). In 2013, substantial proportions of the catch were at age 5 (25%), age 6 (27%) and age 7 (18%) by number. In 2014, the catch consisted of 23% age 3, 15% ages 4 and 5 respectively, 23% age 6 and 14% age 7 (Figure 11).

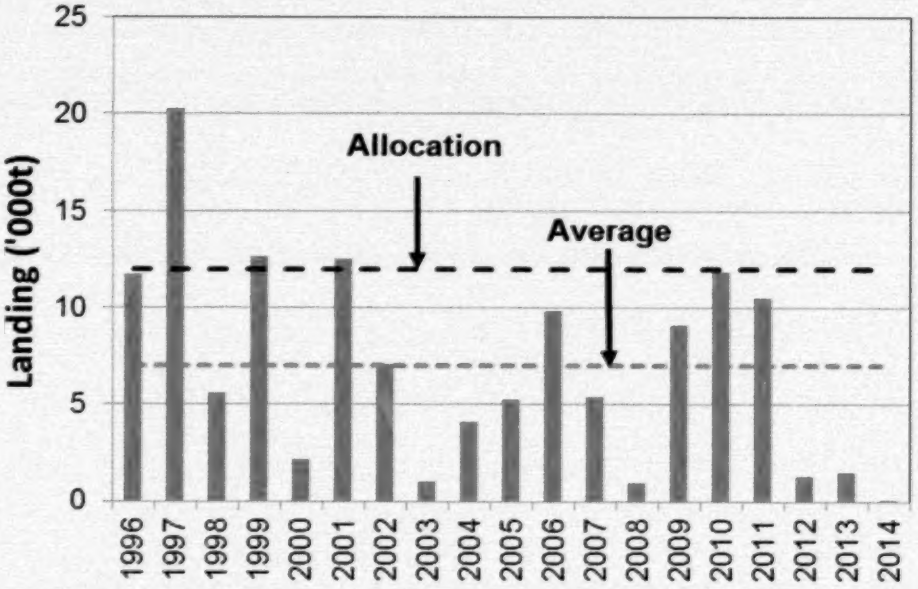


Figure 10. Offshore Scotian Shelf herring landings (includes bycatch in other fisheries) since 1996 with overall average for the period.

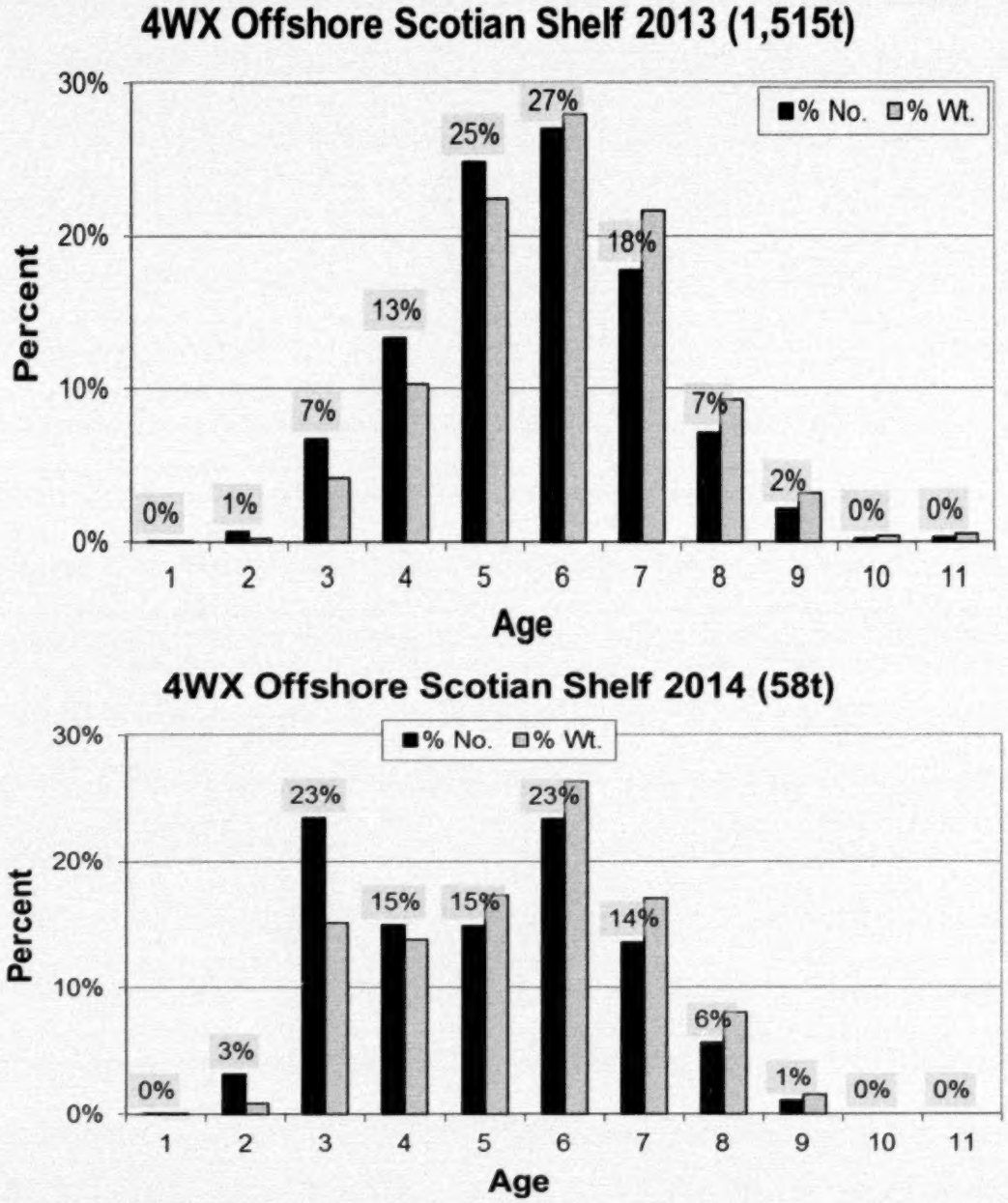


Figure 11. Fishery catch at age (% numbers and % weight) for the 2013 and 2014 Offshore Scotian Shelf herring component.

No industry surveys were conducted on the offshore Scotian Shelf in 2013 or 2014. In the fall of 2014, industry conducted searches in the offshore but failed to find any spawning aggregations. In recent years, summer research bottom trawl surveys have indicated a relatively widespread herring distribution on the Scotian Shelf (Power et al. 2013; Singh et al. 2014). The bottom trawl data, while useful for documenting size, maturity, and distribution, are not considered indicative of overall herring abundance (Power et al. 2013).

In the absence of recent information about stock status, there is no basis for evaluating the current 12,000t catch allocation. The industry is again encouraged to explore and undertake structured surveys of the offshore area.

Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia

There is no quota for the coastal Nova Scotia spawning component. Harvest levels from these areas use 10% of a five-year rolling average of survey biomass to set allocations.

Apart from the four areas indicated in Table 4, the size and historical performance of various spawning groups are poorly documented. In addition to the traditional bait and personal-use fisheries, directed roe fisheries have occurred on several spawning grounds since 1996.

Table 4. Recorded landings and allocations (tonnes) of herring from major gillnet fisheries on the Coastal Nova Scotia spawning component for 2000 to 2014.

Landings (t)		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Avg. Catch Last 5 yr.	Avg. Catch All Years
Little Hope/Port Mouton	Catch	2,043	2,904	3,982	4,526	1,267	2,239	3,133	1,508	1,108	3,731	3,106	2,576	2,150	2,499	3,596	2,785	2,498
	Allocation	1,495	1,170	1,410	2,248	3,028	3,162	3,953	4,008	2,944	2,172	2,454	2,094	2,188	2,787*	3,577	-	-
Halifax/Eastern Shore	Catch	1,350	1,898	3,334	2,727	4,176	3,446	3,348	3,727	2,381	6,045	2,302	908	771	1,390	1,163	1,307	2,331
	Allocation	1,425	1,313	1,403	1,952	3,638	3,802	4,323	5,367	5,103	3,857	4,373	4,188	2,920	2,427	1,959	-	-
Glace Bay	Catch	834	1,204	3,058	1,905	1,481	626	85	45	12	4	11	0	7	2	1	4	679
Bras d'Or Lakes	Catch	56	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	29
Total		4,280	6,004	10,369	9,109	6,981	6,316	6,575	5,275	3,468	9,620	5,419	3,484	2,928	3,891	4,760	4,096	5,536

*original allocation of 2,387t was increased by 400t

Landings and allocations in the Little Hope/Port Mouton area decreased from 2009 to 2012, but increased over the previous two years (Table 4). In 2013, 2,499t were landed against an allocation of 2,787t and, in 2014, 3,596t were landed against an allocation of 3,577t. In the Eastern Shore area, landings increased from 771t in 2012 to 1,390t in 2013 and then decreased in 2014 to 1,163t. Allocation for the Eastern Shore area decreased from 2,920t in 2012 to 1,959t in 2014. Allocations in 2013 and 2014 were based on the recent five-year average of observed acoustic biomass. Landings were minimal for Glace Bay with 2t in 2013 and 1t in 2014. The Bras d'Or Lakes area remained closed to herring fishing. In 2013, the age composition of the landings for the coastal component was primarily adult herring from the size selective gillnet fishery with a substantial proportion of the catch (96%) age 5 and older. In 2014, the catch at age for the same component shifted slightly younger as 19% of the fish were age 3 or 4 (Figure 12).

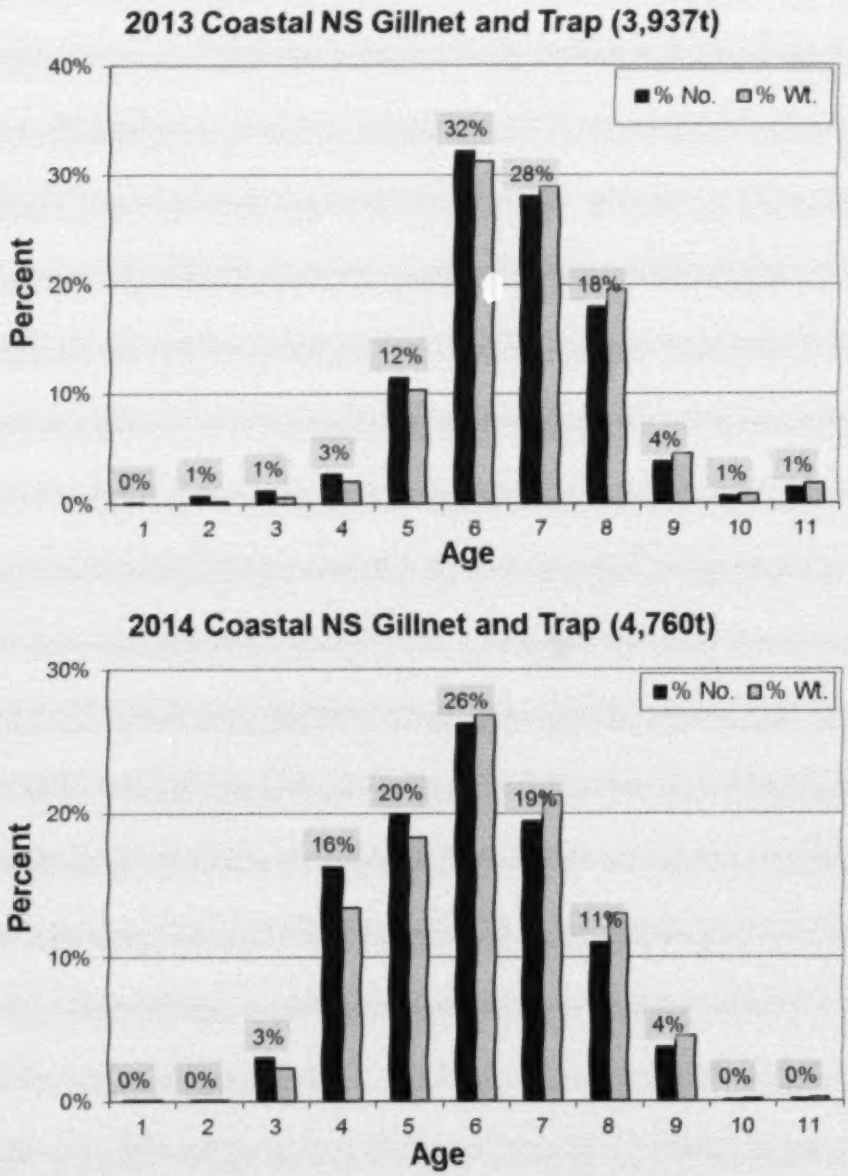


Figure 12. Fishery catch at age (% numbers and % weight) for the 2013 and 2014 Coastal Nova Scotia (gillnet and trap) herring component.

As the inshore roe gillnet fisheries off Glace Bay, East of Halifax, and Little Hope developed (since 1996), participants have contributed to sampling and surveying. In 2013, the total spawning biomass estimate for the Little Hope area was 74,532t. This represents a substantial increase in the spawning biomass estimate over the four-year low in 2012 of 12,756t. The total spawning biomass estimate for the Little Hope area was 46,077t in 2014, which is approximately 28,000t less than in 2013 but is still above the five-year average of 37,664t (Table 5, Figure 13). The total spawning biomass estimate in the Halifax/Eastern shore area was 6,870t in 2013, which represents an increase over the 2012 estimate of 3,668t in spawning biomass. The estimated total spawning biomass increased again in

2014 to 9,586t which is near the five-year average of 10,664t, but well below the long term average (1998-2014) of 28,857t (Figure 14). There was only one acoustic survey conducted in the Glace Bay survey box, which occurred on September 11, 2013. The acoustic survey was on two separate schools of herring. The final 2013 biomass estimate for Glace Bay was 50t (Figure 15). No herring surveys have been conducted in the Bras d'Or Lakes since 2000.

Table 5. Estimated herring acoustic SSB (thousands of tonnes) and recent five-year average for the Coastal Nova Scotia spawning component areas. n/s denotes no survey.

Location	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Avg. last 5 yrs.	Avg. all yrs.
Little Hope/ Port Mouton	15.8	5.2	21.3	56.0	**53.1**	22.5	44.7	24.1	2.8	14.5	36.6	26.7	28.8	12.8	74.0	46.1	37.7	29.4
Halifax/ Eastern Shore	20.2	**10.9**	16.7	**41.5**	92.6	28.4	37.0	68.9	28.3	30.3	54.2	27.7	5.5	3.7	6.9	9.6	10.7	28.9
Glace Bay	2.0	n/s	21.2	7.7	31.5	n/s	3.2	n/s	0.2	0.5	0.1	0.0	0.0	n/s	0.0	n/s	0.0	6.0
Bras d'Or Lakes	05	0.07	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	0.3

Note: Cells with orange border includes mapping surveys which estimated biomass based on visual sounder estimates; bold text in cells includes mapping and acoustic surveys. Data prior to 2003 calculated with the Calibration Integration Factor are not available.

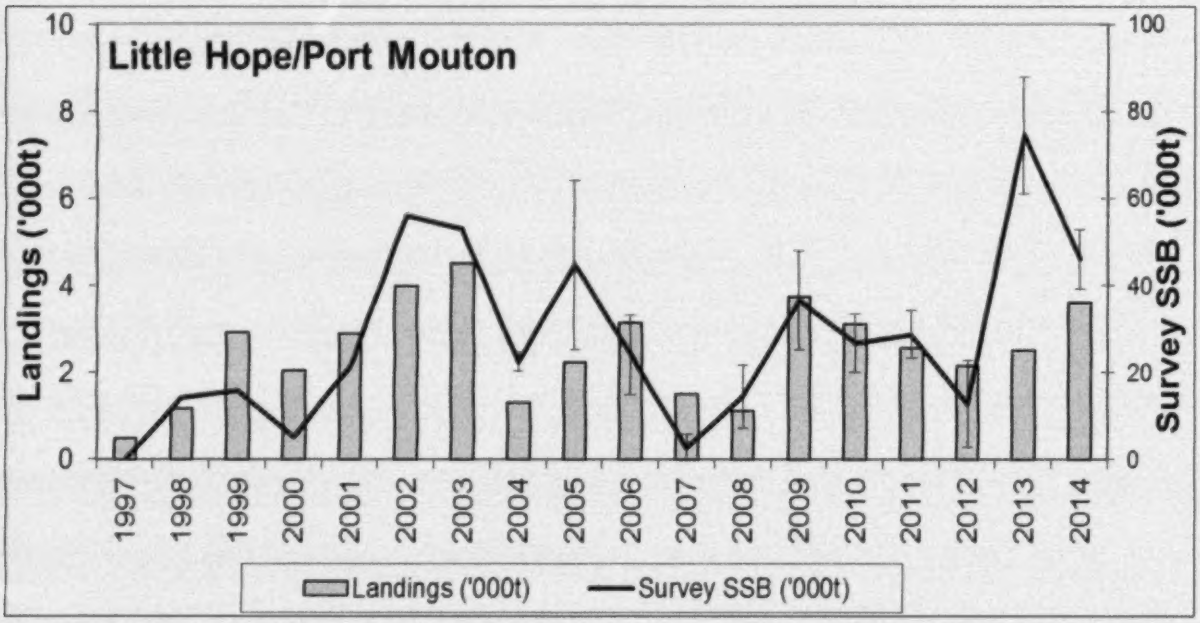


Figure 13. Landings and acoustic survey SSB with 95% C.I. ('000t) for the Little Hope/Port Mouton gillnet fishery for 1997-2014. No C.I. could be calculated for years prior to 2004.

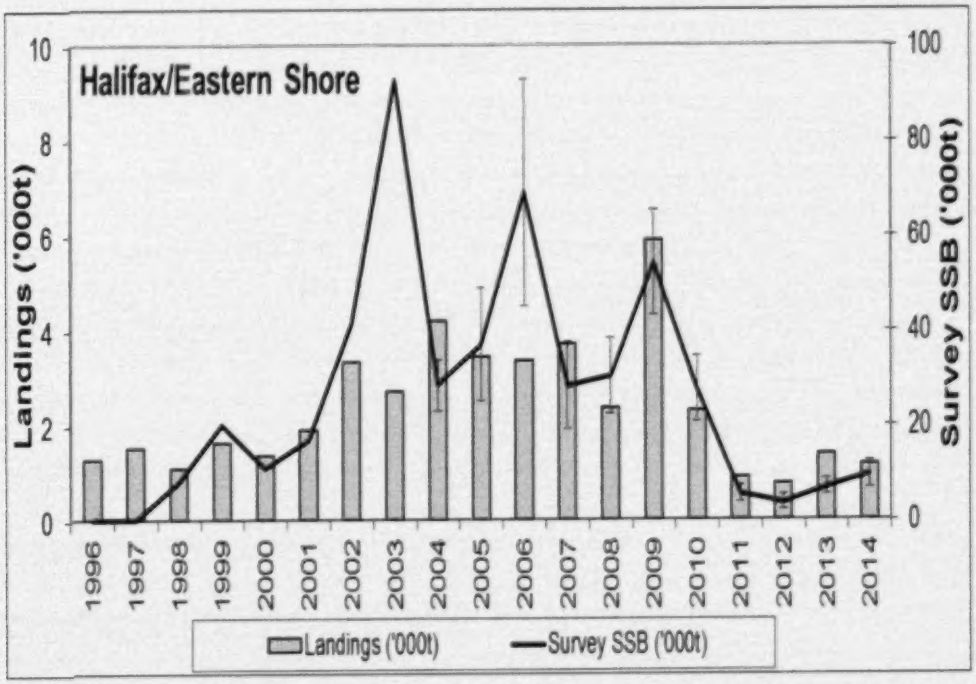


Figure 14. Landings and acoustic survey SSB with 95% C.I. ('000t) for the Halifax/Eastern Shore gillnet fishery for 1996-2014. No C.I. could be calculated for years prior to 2004.

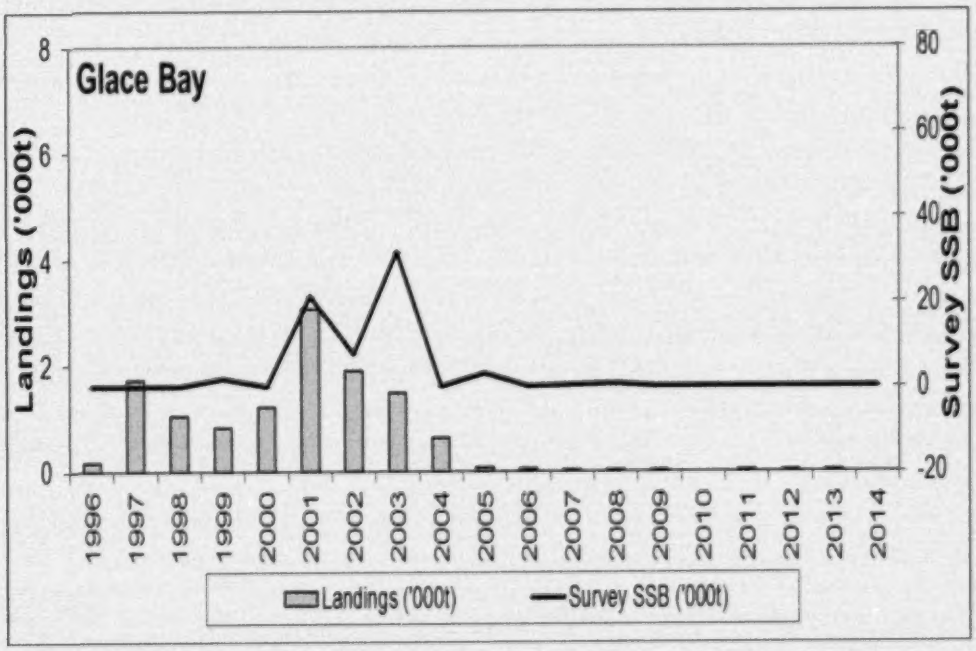


Figure 15. Landings and acoustic survey SSB ('000t) for the Glace Bay gillnet fishery for 1996-2014. No C.I. could be calculated due to limited number of surveys.

Collaborative surveys with industry have improved our knowledge of two areas (Little Hope/Port Mouton, Halifax/Eastern Shore), but there has been no increase in information from other areas. The

Glace Bay area was last surveyed in 2013. Individual spawning groups within the coastal component are considered vulnerable to fishing because of their relatively small size (biomass) and proximity to shore. It is again recommended that no coastal spawning group experience a large effort increase in new areas until information on abundance and movement is available to evaluate the state of that spawning group.

It has been noted since 1997 that the status of herring in the Bras d'Or Lakes is cause for concern. In the absence of current abundance information the Bras d'Or Lakes should remain closed.

Southwest New Brunswick Migrant Juveniles

The southwest New Brunswick weir and shutoff fisheries have relied, for over a century, on the aggregation of juvenile herring (ages 1-3) near shore at the mouth of the Bay of Fundy. These fish are considered to be a mixture of juveniles, dominated by those originating from Northwest Atlantic Fisheries Organization (NAFO) Subarea 5 spawning components, and have, therefore, been excluded from the SWNS/BoF quota.

Landings in the New Brunswick weir and shut-off fishery increased from the historic low in 2012 of 504t to 6,431t in 2013. In 2014, landings decreased to 2,149t, the second lowest since 1963. It is notable that in 2007 landings were 30,944t, the highest in nearly 20 years and higher than the long term average of 21,752t (Figure 16). For the times series presented, current landings are at or near the lowest observed. The age distribution of fish caught in the New Brunswick weir and shutoff fishery were mostly juveniles ages 1 or 2, making up 93% in 2013 and 96% in 2014 (Figure 17). The number of weirs with landings increased from a historical low of four in 2012 to 49 in 2013, then decreased to 26 in 2014.

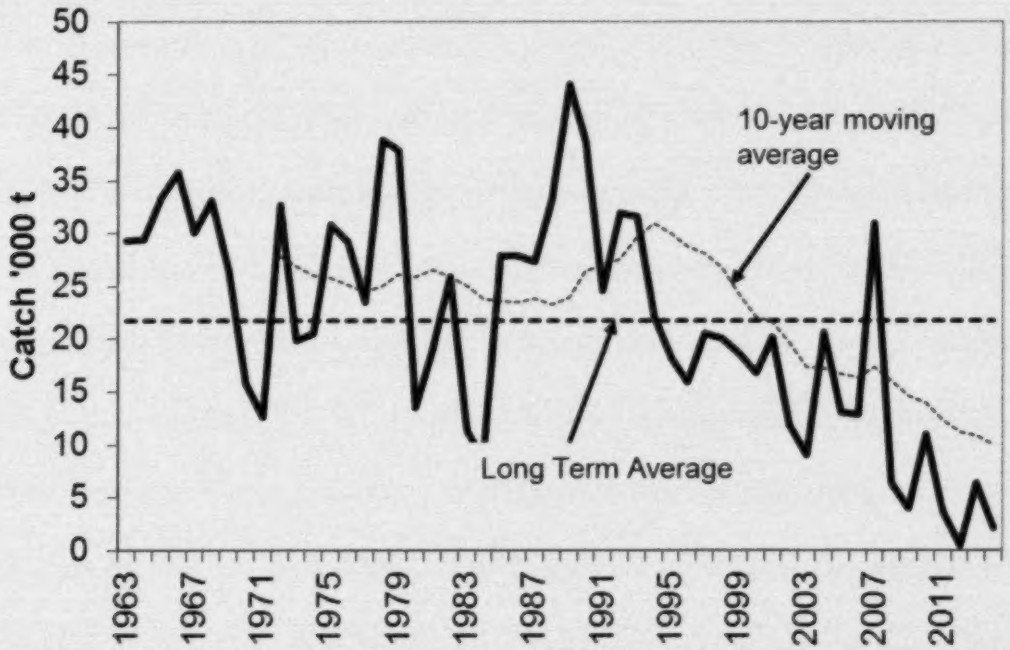


Figure 16. Herring landings from New Brunswick weir and shutoff fishery for 1963-2014 with long term average and 10-year moving average.

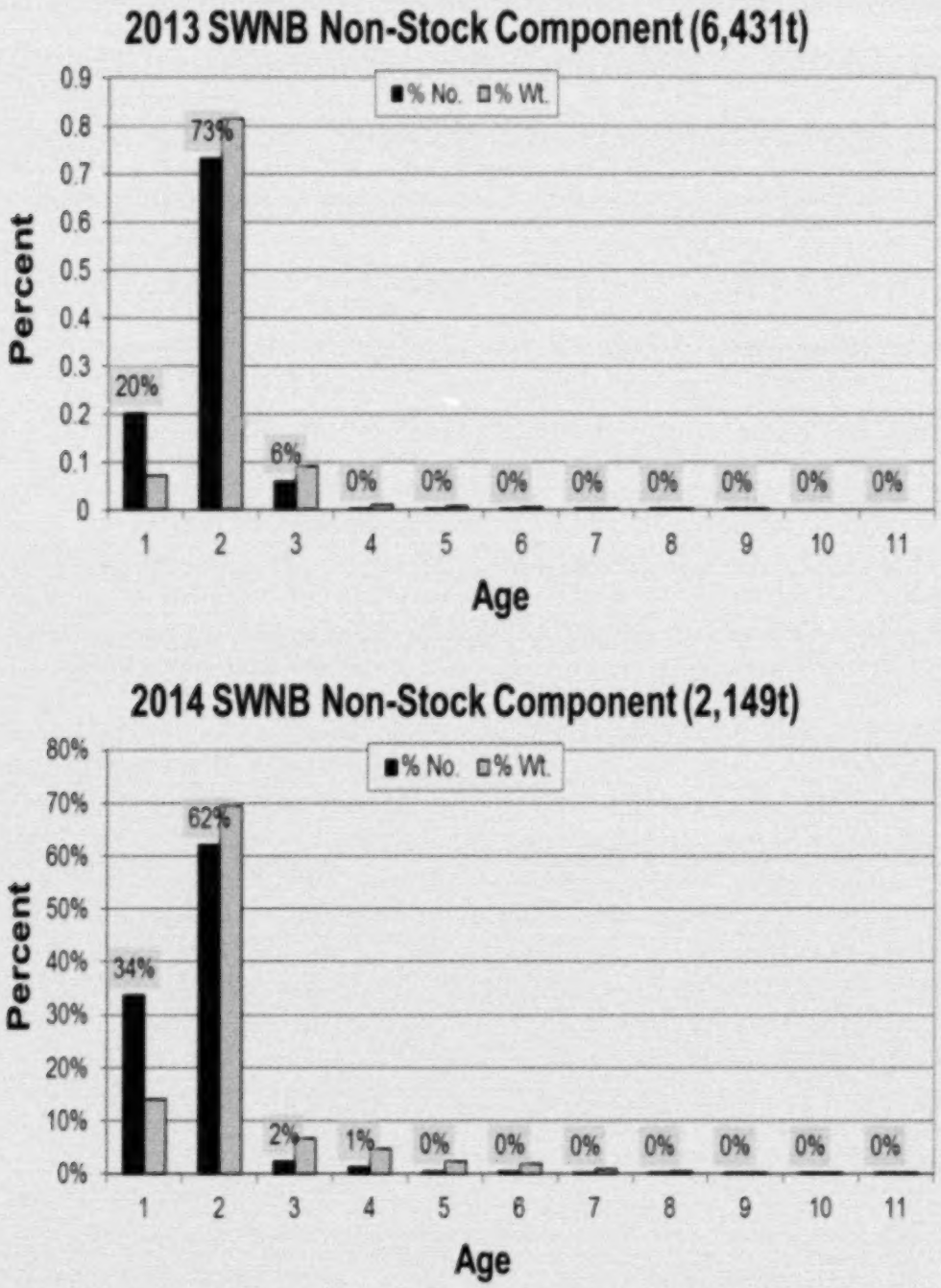


Figure 17. Fishery catch at age (% numbers and % weight) for the 2013 and 2014 SW New Brunswick migrant juvenile herring component.

The landings time series for this fishery may not be indicative of abundance because catches are extremely susceptible to many factors in addition to abundance, including effort.

Sources of Uncertainty

SW Nova Scotia/Bay of Fundy

Acoustic surveys are a valuable tool for the assessment of this fishery and methods continue to be improved. Uncertainty remains for several factors including estimation of biomass in the acoustic dead/blind zones at the surface and close to bottom, the assumption that the surveys are additive, and residence time on the spawning grounds. A review of the tagging study by Melvin et al. (2014) on German Bank could help reduce uncertainty about residence time.

Recruitment into this fishery by year class has been highly variable and as is the case with most fisheries the size of recruiting year class is unknown, leading to uncertainty in future abundance changes.

The mechanisms causing changes in fish weight-at-age are not understood.

Advice on stock status uses relative trends in spawning stock biomass and exploitation rate because there is no accepted analytical assessment model. This creates a difficulty in putting current SSB in a historical context as acoustic data only exist for 1999-2014.

Offshore Scotian Shelf Banks

Age distribution data are often interpreted as a proxy for survival. However, variability in cohort size or the targeting of different age classes will also influence the age distribution in a given year. As such, there is uncertainty whether the more evenly distributed age classes observed for the offshore in 2013 compared to 2014 is a result of changes in survival or recruitment.

In the absence of recent information on stock status, there is no basis for evaluating the current 12,000t catch allocation. The industry is again encouraged to explore and undertake structured surveys of the offshore area.

Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia

The age distribution data is often interpreted as a proxy for survival. However, variability in cohort size or the targeting of different age classes will also influence the age distribution in a given year. As such, interpretation of changes in the age distribution from 2013 to 2014 is unclear.

The survey method used to estimate abundance in this component differed from that used in SWNS/BoF. One difference is the way in which surveys were included, excluded, or combined, which may overestimate abundance.

With the exception of the four main areas, the size of various additional spawning groups and landings from these groups are poorly documented. In addition to the traditional bait and personal-use fisheries, directed roe fisheries have occurred on several spawning grounds since 1996.

The Glace Bay area has not been surveyed since 2013.

No herring surveys have been conducted in the Bras d'Or Lakes since 2000.

Southwest New Brunswick Migrant Juveniles

The primary sources of information for assessing this component are the landings, which have declined markedly from the 1980s to present. The landings time series for this fishery may not be indicative of abundance because catches are extremely susceptible to many factors in addition to abundance, including effort.

The relative contribution of various spawning components to this fishery is unknown (e.g., Subarea 5, SWNS/BoF, etc.).

CONCLUSIONS AND ADVICE

SW Nova Scotia/Bay of Fundy

Although there is uncertainty associated with the biomass estimates, longer term trends in biomass appear to be evident for the SWNS/BoF spawning component: a decreasing trend in the German Bank area from 1999 to present and an increasing trend in the Scots Bay area since 2005. The three-year moving average increased above the LRP in 2011 and changed very little in 2012. Since 2012, the three-year moving biomass average has been increasing slightly each year. Biomass estimates have fluctuated about the LRP since 2010. Confidence intervals include the LRP in three of the last four years, the exception being 2012 when the confidence interval was above the LRP.

The biomass of spawning fish estimated to be on Trinity Ledge from 2012 to 2014 is low relative to values observed in the early 2000s. Fishing during the spawning season on Trinity Ledge has the potential to jeopardize the persistence of this spawning unit.

The broad range of ages observed in the commercial catch indicates that the conservation objective to maintain a broad range of ages is generally being met.

A harvest strategy, which continues to exercise caution, is appropriate.

Offshore Scotian Shelf Banks

Since 1996, a fishery has occurred on feeding aggregations on the offshore banks, primarily in May and June, with catches ranging from 20,261t in 1997 to 58t in 2014. Landings from 2012 to 2014 were amongst the lowest in the time series.

No industry surveys were conducted on the offshore Scotian Shelf in 2013 or 2014. In the fall of 2014 industry conducted searches in the offshore, but failed to find any spawning aggregations.

Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia

From 2009 to 2014, landings in the Little Hope/Port Mouton area have ranged between 2,150t and 3,731t, and have been near or above the allocation.

From 2009 to 2014, landings in the Eastern Shore area have ranged between 771t and 6,045t, and are generally below the allocation.

Landings were minimal for Glace Bay with 2t in 2013 and 1t in 2014.

The Bras d'Or Lakes area remained closed to herring fishing. It has been noted since 1997 that the status of herring in the Bras d'Or Lakes is cause for concern. In the absence of current abundance information the Bras d'Or Lakes should remain closed.

Individual spawning groups within the coastal component are considered vulnerable to fishing because of their relatively small size (biomass) and proximity to shore. For this reason, a large effort increase in new areas has a potential to markedly reduce abundance in the absence of information about the status of the specific spawning group.

Southwest New Brunswick Migrant Juveniles

Landings in the New Brunswick weir and shut-off fishery increased from the historic low in 2012 of 504t to 6,431t in 2013. In 2014, landings decreased to 2,149t, the second lowest since 1963. It is notable

that in 2007 landings were 30,944t, the highest in nearly 20 years and higher than the long term average of 21,752t.

For the time series presented, current landings are at or near the lowest observed. In 2012, the number of weirs with landings was at a historical low, but subsequently increased to 49 in 2013. In 2014, the number of weirs with catches again decreased to 26.

Abundance of herring available to the weirs is unknown.

OTHER CONSIDERATIONS

In 2013, observer reports indicated no by-catch of non-herring species in the purse seine sets. In 2014, by-catch consisted of small amounts of Silver Hake, Mackerel (Atlantic), Porbeagle Shark, Spiny Dogfish and American Lobster, and a single Bluefin Tuna. All by-catch was released with the exception of very small quantities of Silver Hake, Mackerel (Atlantic), and Spiny Dogfish.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 25-26, 2015, Assessment of 4VWX Herring. Additional publications from this process will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Clark, D.S., K.J. Clark, R. Claytor, S. Leslie, G.D. Melvin, J.M. Porter, M.J. Power, H.H. Stone, andC. Waters. 2012. Limit Reference Point for Southwest Nova Scotia / Bay of Fundy spawning component of Atlantic herring, *Clupea harengus* (German Bank and Scots Bay). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/025. iii + 14 p.

DFO. 2003. 2003-2006 Scotia-Fundy Fisheries Integrated Herring Management Plan, NAFO subdivisions 4WX, 4Vn and 5Z. Department of Fisheries and Oceans.

DFO. 2007. Proceedings of the Maritimes Provinces Regional Advisory Process on the assessment framework for 4VWX herring stocks; 31 October–1 November 2006 and 9–11 January 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2007/002: 52 p.

DFO. 2011. Proceedings of the Maritimes Provinces Regional Advisory Process on the Assessment Framework for Southwest Nova Scotia/Bay of Fundy Herring; 24 – 28 January 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2011/031.

Melvin, G.D., R. Martin, and M.J. Power. 2014. Estimating German Bank and Scots Bay Herring Spawning Ground Turnover Rates from Tag Returns. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/068: iv + 22 p.

Power, M.J., D. Knox, A. MacIntyre, G.D. Melvin, and R. Singh. 2013. 2011 Evaluation of 4VWX Herring. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/085: iv + 85 p.

Sinclair, M. (Chair). 1997. Report of the Maritimes Region Herring Workshop, 18-19 February 1997. Can. Stock Assess. Proceed. Ser. 97/12: 58 p.

Singh, R., Melvin, G.D., Clay, A., and Power, M.J. 2014. Summary of 2011 and 2012 Herring Acoustic Surveys in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4VWX. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/067. v + 147 p.

THIS REPORT IS AVAILABLE FROM THE:

Centre for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
P.O. Box 1006, Stn. B203
Dartmouth, Nova Scotia

Telephone: 902-426-7070
E-Mail: XMARMRAP@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
© Her Majesty the Queen in Right of Canada, 2015

Correct Citation for this Publication:

DFO. 2015. 2015 Assessment of 4VWX Herring. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/040.

Aussi disponible en français :

MPO. 2015. Évaluation du hareng de 4VWX de 2015. Secr. can. de consult. sci. du MPO, Avis sci. 2015/040.